



VERIFICATION OF TRANSLATION

Re: JAPANESE PATENT APPLICATION NO.2002-11337

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hereby declare that I am the translator of the  
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true translation to the best of my knowledge and  
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[Title of the Invention] METHOD FOR FABRICATING A NITRIDE  
SEMICONDUCTOR DEVICE

[Claims]

[Claim 1] A method for fabricating a nitride  
5 semiconductor device comprising the steps of:

in a multi-layered substrate having a first  
conductive III-V group nitride semiconductor layer and a  
second conductive III-V group nitride semiconductor layer  
formed on the first conductive semiconductor layer,

10 forming irregularities in the surface of the  
substrate by first and second etching steps, wherein the  
first etching step forms a ridge stripe by etching  
portions of the second conductive semiconductor layer,  
and the second etching step exposes the first conductive  
15 semiconductor layer,

forming an embedded insulating film on the  
surface of the substrate to fully embed the irregularities  
in the surface of the substrate, and

flattening the insulating film.

20 [Claim 2] The method for fabricating a nitride  
semiconductor device according to Claim 1, wherein the  
embedded insulating film comprises a silicon oxide film or  
a silicon nitride film.

[Claim 3] The method for fabricating a nitride  
25 semiconductor device according to Claim 1 or 2, wherein

the embedded insulating film contains metal fine particles or semiconductor fine particles.

[Claim 4] The method for fabricating a nitride semiconductor device according to any one of Claims 1 to 3,  
5 wherein the flattening step is conducted by a CMP method or a resist etch-back method.

[Detailed Description of the Invention]

[0001]

[Technical Field to Which the Invention Pertains]

10 The present invention relates to a fabricating method of a semiconductor laser and like nitride semiconductor devices, the application of which is anticipated in the field of optical information processing.

[0002]

15 [Prior Art]

Nitride semiconductors that contain nitrogen (N) as the Group V element are excellent candidates for useful materials as short-wavelength light emitting devices because of their wide band gap. Among these, extensive  
20 research has been conducted on gallium nitride-based compound semiconductors (GaN-based semiconductors:  $\text{Al}_x\text{Ga}_y\text{In}_z\text{N}$  ( $0 \leq x, y, z \leq 1 (x+y+z=1)$ ), and blue light emitting diodes (LEDs) and green LEDs have already been put to practical use. Furthermore, in order to increase the  
25 storage capacity of optical disc apparatuses, a

semiconductor laser with an oscillation wavelength in the 400-nm band is necessary. For this reason, semiconductor lasers using GaN-based semiconductors have attracted widespread attention, and are now approaching the level of  
5 practical use.

[0003]

A process for fabricating a prior-art GaN-based semiconductor laser is explained below with reference to Fig. 2.

10 [0004]

(a) First, by metal organic chemical vapor deposition (MOVPE), a multi-layered structure comprising a GaN-buffer layer (not shown), n-GaN layer 202, n-AlGaN cladding layer 203, n-GaN optical guide layer 204, multi-  
15 quantum well (MQW) active layer 205 composed of  $Ga_{1-x}In_xN/Ga_{1-y}In_yN$  ( $0 < y < x < 1$ ), p-GaN second optical guide layer 206, p-AlGaN cladding layer 207, and p-GaN contact layer 208 is formed on a sapphire substrate 201.

[0005]

20 (b) Next, photolithography is used to form a striped resist pattern (not shown) on the p-GaN contact layer 208. Then, using this resist pattern as a mask, a reactive-ion-etching method using a chlorine-based gas is employed to etch portions of the p-GaN contact layer 208  
25 and the p-AlGaN cladding layer 207 to obtain a ridge

stripe having a width of approximately 2  $\mu\text{m}$  on the surface of the substrate.

[0006]

Thereafter, photolithography is used to form a  
5 wide striped resist pattern (not shown) that has a width of several dozen  $\mu\text{m}$  to several hundred  $\mu\text{m}$  in such a positional relationship that the ridge stripe is covered by the resist pattern. Then, using this resist pattern as a mask, a reactive-ion-etching method using a chlorine-  
10 based gas is employed to etch the surface of the substrate to expose the n-GaN layer 202.

[0007]

After removing the resist mask, for example, by employing plasma CVD using  $\text{SiH}_4$  and  $\text{N}_2\text{O}$  as source  
15 materials, a silicon oxide film 209 having a thickness of several hundred to several thousand  $\text{\AA}$  is deposited on the surface of the substrate.

[0008]

The p-GaN contact layer 208 and n-GaN layer 202  
20 on the ridge stripe are exposed by partially etching the silicon oxide film 209 to form a p-type electrode 210 made of Ni/Au on the p-GaN contact layer 208 and an n-type electrode 211 made of Ti/Al on the n-GaN layer 202.

[0009]

25 (c) Thereafter, the substrate is cleaved and

separated to form a chip. The chip is then mounted on a sub-mount 212. The sub-mount 212 comprises a SiC substrate 213, patterned wires 214 on the substrate, and solder 215 on the wires. The p-type electrode 210 and n-type electrode 211 on the surface of the chip are adhered to the wires 214 on the sub-mount by melting the solder 215 and pressing the chip tightly against the sub-mount 212.

[0010]

10 In this semiconductor device, when voltage is applied across the n-type electrode and the p-type electrode, positive holes from the p-type electrode 210 and electrons from the n-type electrode 211 are injected into the MQW active layer 205, causing the laser to oscillate with a wavelength in the 400-nm band by generating optical gain in the MQW active layer 205. The oscillation wavelength varies depending on the composition or thickness of the  $\text{Ga}_{1-x}\text{In}_x\text{N}/\text{Ga}_{1-y}\text{In}_y\text{N}$  thin film that is a material for the MQW active layer 205. Currently, continuous oscillation at room temperature and higher temperature are being put to practical use.

[0011]

[Problem to Be Solved by the Invention]

Usually, to enhance the reliability of a semiconductor laser, it is desirable to improve the heat

diffusion properties of the device. As a means for improving the heat diffusion properties of the device, there is a packaging technique that is the so-called junction-down configuration, wherein, as described in the prior art, the surface of the substrate in the vicinity of the p-n junction is made to contact the sub-mount which has a high heat conductive property.

[0012]

However, in a case of a semiconductor laser formed on a sapphire substrate, because sapphire is insulative, it is necessary to form both the p-type electrode and n-type electrode on the surface of the substrate, making a difference in levels of approximately 2  $\mu\text{m}$  on the surface of the substrate. Such a big difference in levels may cause incomplete adhesion of solder connecting the device side electrode and sub-mount side electrode.

[0013]

The present invention aims at solving the above problems and providing a fabrication method for improving the yield in fabricating nitride semiconductor lasers formed on sapphire substrates.

[0014]

[Means for Solving the Problem]

The method for fabricating a nitride

semiconductor device of the present invention comprises the steps of forming an embedded insulating film in the surface of a substrate having irregularities formed by etching, and flattening the surface.

5 [0015]

[Mode for Carrying Out the Invention]

Embodiments of the present invention are explained with reference to drawings.

[0016]

10 (Embodiment 1)

A process of fabricating a GaN-based semiconductor laser of the present invention is explained with reference to Fig. 1.

[0017]

15 (a) First, by metal organic chemical vapor deposition (MOVPE), a multi-layered structure comprising a GaN-buffer layer (not shown), n-GaN layer 102, n-AlGaN cladding layer 103, n-GaN optical guide layer 104, multi-quantum well (MQW) active layer 105 composed of  $Ga_{1-x}In_xN/Ga_{1-y}In_yN$  ( $0 < y < x < 1$ ), p-GaN second optical guide layer 106, p-AlGaN cladding layer 207, and p-GaN contact layer 108 is formed on a sapphire substrate 101.

[0018]

25 (b) Next, photolithography is used to form a striped resist pattern (not shown) on the p-GaN contact



layer 108. Then, using this resist pattern as a mask, a reactive-ion-etching method using a chlorine-based gas is employed to selectively etch portions of the p-GaN contact layer 108 and the p-AlGaN cladding layer 107 to obtain a  
5 ridge stripe having a width of approximately 2  $\mu\text{m}$  on the surface of the substrate.

[0019]

Thereafter, photolithography is used to form a wide striped resist pattern (not shown) that has a width  
10 of several dozen  $\mu\text{m}$  to several hundred  $\mu\text{m}$  in such a positional relationship that the ridge stripe is covered by the resist pattern. Then, using this resist pattern as a mask, a reactive-ion-etching method using a chlorine-based gas is employed to etch the surface of the substrate  
15 to expose the n-GaN layer 202. The thickness of the etched film in this step is approximately 1  $\mu\text{m}$ . Thereafter, the resist mask is removed.

[0020]

As a result, the difference in the levels of the  
20 highest portion on the substrate, i.e., top of the ridge stripe, and the lowest portion, i.e., exposed portion of the n-GaN layer 202, becomes approximately 2  $\mu\text{m}$ .

[0021]

(c) Then, for example, a plasma CVD method using  
25  $\text{SiH}_4$  and  $\text{N}_2\text{O}$  as source materials is employed to deposit a

silicon oxide film on the surface of the substrate,  
forming an embedded insulating film 109 having a thickness  
of approximately 4  $\mu\text{m}$ . In the present invention, it is  
important to make the thickness of the deposited film  
5 greater than the difference in the levels formed in the  
previously conducted etching step (2  $\mu\text{m}$  in the present  
embodiment).

[0022]

(d) The surface of the oxide film 109 is then  
10 flattened by polishing with, for example, a chemical-  
mechanical polishing (CMP) method.

[0023]

(e) Next, portions of the silicon oxide film 109  
are etched to form contact holes to expose the surfaces of  
15 the p-GaN contact layer 108 and the n-GaN contact layer  
102. Then, a p-type electrode 110 made of, for example,  
Ni/Au, is implanted in the contact hole that communicates  
with the p-GaN contact layer 108, and an n-type electrode  
111 made of, for example, Ti/Al, is implanted in a contact  
20 hole that communicates with the n-GaN contact layer 102.

[0024]

(c) Thereafter, the substrate is cleaved and  
separated to form a chip. The chip is then mounted on a  
sub-mount 112. The sub-mount 112 comprises a SiC  
25 substrate 113, patterned wires 114 on the substrate, and

solder 115 on the wires. The p-type electrode 110 and n-type electrode 111 on the surface of the chip are adhered to the wires 114 on the sub-mount by melting the solder 115 and pressing the chip tightly against the sub-mount  
5 112.

[0025]

In the device of the present invention, when voltage is applied across the n-type electrode and the p-type electrode, positive holes from the p-type electrode  
10 110 and electrons from the n-type electrode 111 are injected into the MQW active layer 105, causing the laser to oscillate with a wavelength in the 400-nm band by generating optical gain in the MQW active layer 105.

[0026]

15 Instead of a plasma CVD method, the embedded insulating film 109 can be formed by using a thermal CVD method, optical CVD method, spin coating method, sputtering, or other known method.

[0027]

20 Furthermore, instead of a silicon oxide film, it is possible to use silicon nitride film, aluminum nitride, and like materials that have a high insulating property as the material for the embedded insulating film 109.

[0028]

25 Note that when an insulating film containing

metal fine particles or semiconductor fine particles having a high thermal conductivity is used as a material for the embedded insulating film 109, it is possible to improve heat diffusion properties of the device.

5 [0029]

[Effects of the Invention]

As described above, the GaN-based semiconductor device of the present invention has a flat surface and therefore incomplete adhesion of solder hardly occurs during the fabrication process. Furthermore, it is possible to improve the heat diffusion properties of the device by using metal fine particles or semiconductor fine particles having a high thermal conductivity as a material for the embedded insulating film.

15 [Brief Description of the Drawings]

Fig. 1 shows a fabrication process of a GaN-based semiconductor laser of the first embodiment.

Fig. 2 illustrates a method for fabricating a prior-art GaN-based semiconductor laser.

20 [Explanation of numerical symbols]

101 sapphire substrate

102 n-GaN layer

103 n-AlGaIn cladding layer

104 n-GaN optical guide layer

25 105 multi-quantum well (MQW) active layer composed of Ga<sub>1-</sub>

- $x\text{In}_x\text{N}/\text{Ga}_{1-y}\text{In}_y\text{N}$  ( $0 < y < x < 1$ )
- 106 p-GaN second optical guide layer
- 107 p-AlGaN cladding layer
- 108 p-GaN contact layer
- 5 109 embedded insulating film
- 110 p-type electrode
- 111 n-type electrode
- 112 sub-mount
- 113 SiC substrate
- 10 114 wire
- 115 solder
- 201 sapphire substrate
- 202 n-GaN layer
- 203 n-AlGaN cladding layer
- 15 204 n-GaN optical guide layer
- 205 multi-quantum well (MQW) active layer composed of  $\text{Ga}_{1-x}\text{In}_x\text{N}/\text{Ga}_{1-y}\text{In}_y\text{N}$  ( $0 < y < x < 1$ )
- 206 p-GaN second optical guide layer
- 207 p-AlGaN cladding layer
- 20 208 p-GaN contact layer
- 209 silicon oxide film
- 210 p-type electrode
- 211 n-type electrode
- 212 sub-mount
- 25 213 SiC substrate



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214 wire

215 solder



[Document Name] Drawing

Fig. 1

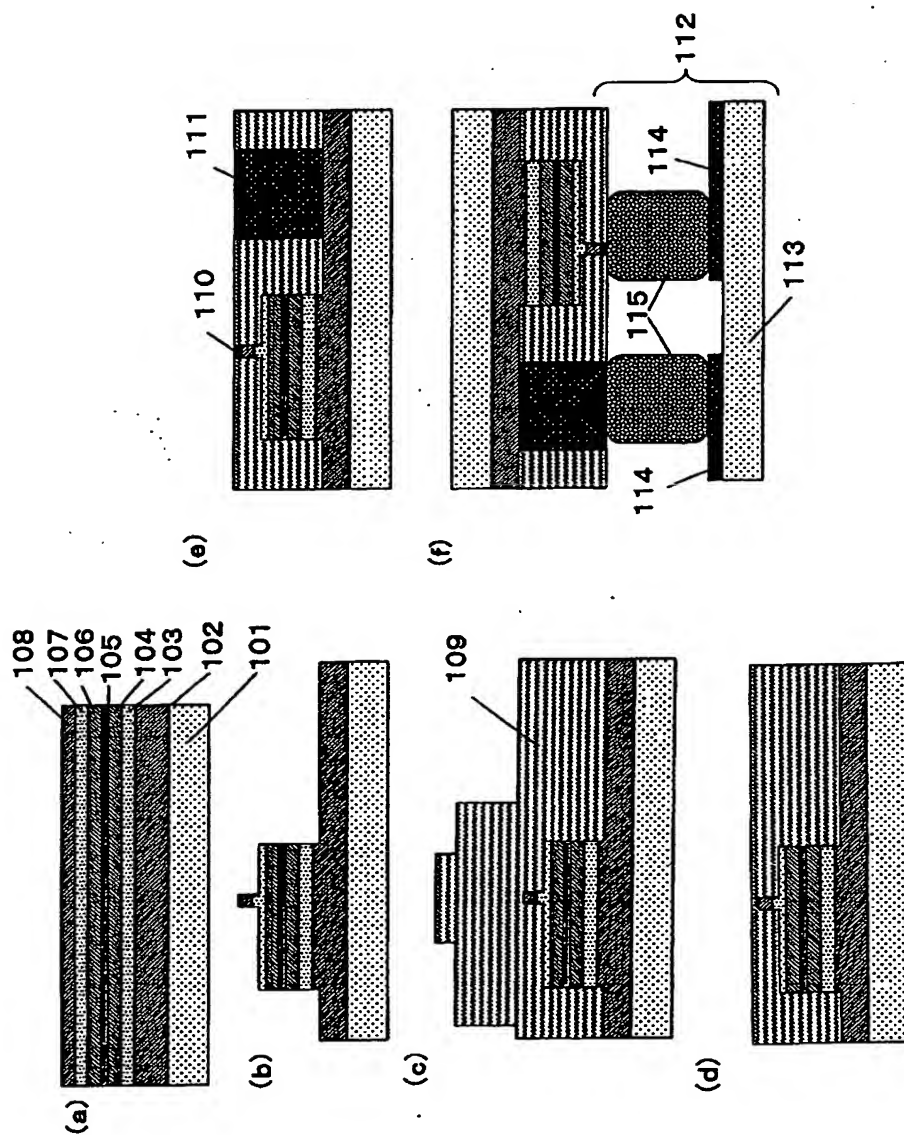
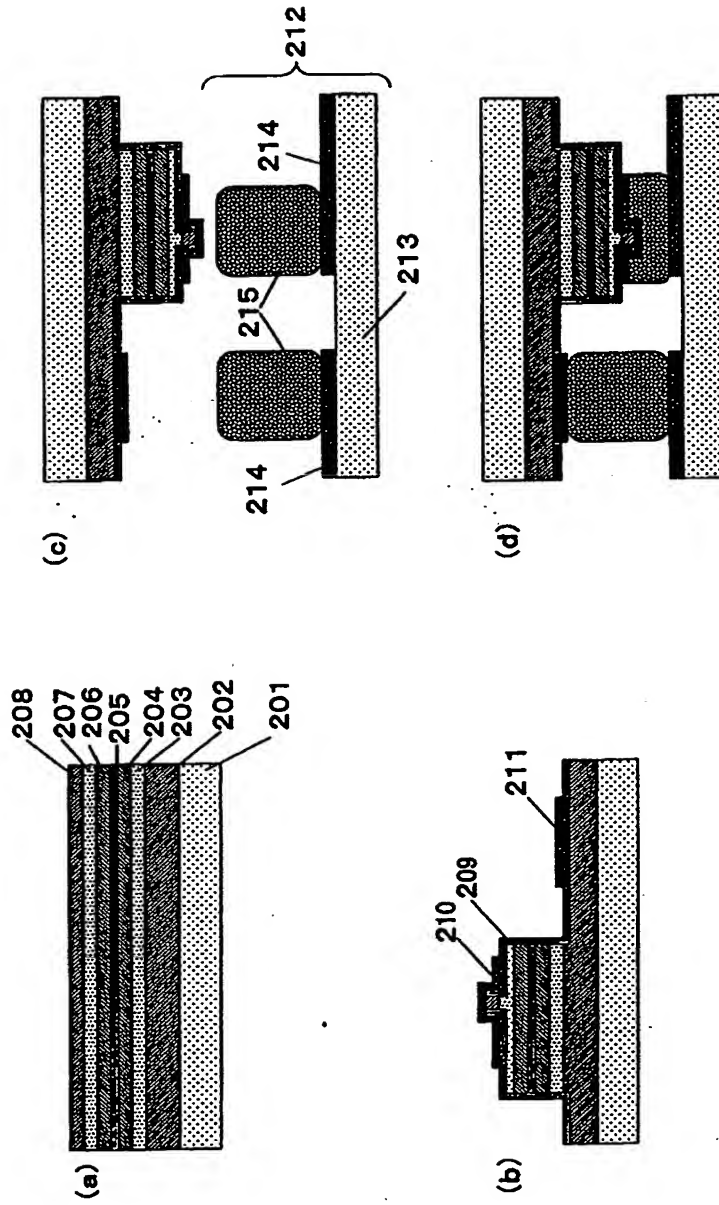


Fig. 2





[Document Name] Abstract

[Abstract]

[Object]

An object of the present invention is to improve  
5 the yield in fabricating GaN-based semiconductor lasers.

[Method for Achieving the Object]

The method for fabricating a nitride  
semiconductor of the present invention comprises the steps  
of forming an embedded insulating film on the surface of  
10 the substrate having irregularities formed by etching, and  
flattening the surface.

[Selected Figure] Fig. 1